

2009

The Effects of platform vibration on Upper Body Muscle Activity During Pushups

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**THE EFFECTS OF PLATFORM VIBRATION
ON UPPER BODY MUSCLE ACTIVITY DURING PUSHUPS**

By

Sadiki Robertson

A Thesis

**Submitted to the Faculty of Graduate Studies
through Kinesiology
in Partial Fulfillment of the Requirements for
the Degree of Master of Human Kinetics at the
University of Windsor**

Windsor, Ontario, Canada

2009

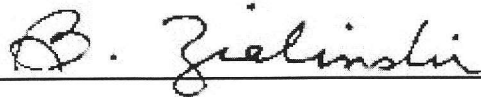
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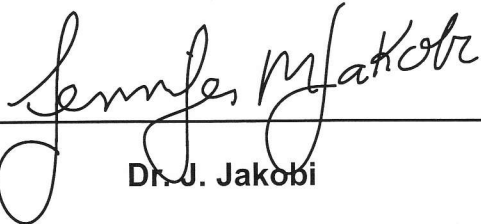
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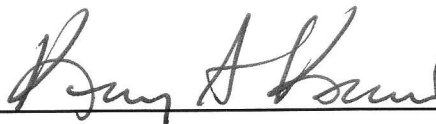
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Today's Date: April 16, 2008
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Department/School: Kinesiology
REB Number: 08-104
Research Project Title: The Effects of Whole Body Vibration on Upper Body Muscular Activation
Clearance Date: April 15, 2008
Project End Date: June 30, 2008

Progress Report Due:
Final Report Due: June 30, 2008

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During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the REB. Minor change(s) in ongoing studies will be considered when submitted on the Request to Revise form.

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Dr. Maureen Muldoon

Maureen Muldoon, Ph.D.
Chair, Research Ethics Board

cc: Dr. Kenji Kenno, Kinesiology
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Abstract

The main objective of this study was to determine the optimal vibrating platform frequency and amplitude to stimulate increases in EMG muscle activity in the pectoralis major (PM), latissimus dorsi (LD), triceps brachii (TB), and bicep brachii (BB) during pushups. Fifteen subjects performed pushups with no vibration (NV), or random frequency (25, 35, 45 Hz) and amplitude (2 or 4 mm) combinations. Ratings of perceived exertion (RPE) and heart rate (HR) were collected following each condition. RPE data did not consistently demonstrate that vibration was significantly different from NV, and HR did not vary between conditions. The only statistically significant ($p < 0.05$) increase in EMG_{RMS} muscle activity over NV was demonstrated at the 45Hz, 4mm condition in the TB (4.37 ± 1.48 %MVE), and BB (7.64 ± 2.5 %MVE). No other vibration conditions had an effect on PM, LD, TB, or BB muscle activity.

Acknowledgements

I would first like to thank my graduate school advisor Kenji Kenno for his patience and tutelage through all my years spent here at the University of Windsor. Kenji has taught me intelligence is important, but also that character should not be forgotten. You have encouraged me to succeed even when it wasn't easy and I'm very grateful for having had the opportunity to work with you on this project.

I would like to extend my sincere thanks to Jim Potvin, Nancy McNevin, and Jennifer Jakobi who have also been very helpful to me in the pursuit of my Master's degree. Jim Potvin was very helpful providing me with guidance upon the completion of my bachelor's degree. Nancy, thank you for taking the time to go through my stats with me and answer any questions I had. I am no expert, but feel like I have a comfortable understanding of the statistics that I ran. Jenn, you were also pivotal in answering many of my statistics and paper related questions, and you were willing to help me make my final push for the finish line. All of your contributions are much appreciated.

I would also like to extend my thanks to Ruth Brown for aiding with my data collection. Time would have gone by much slower in the lab had not been for your smile and positive attitude. Good luck to you with your future education.

To my future wife Geniene, I just want to say that I love you, and am so grateful for your patience and support while pursuing my Master's degree. You were always there to let me know that the next day, or the next draft would be better. You mean the world to me.

Lastly, I would like to thank my family and friends. I am very lucky to be surrounded by so many people who support my ambitions and genuinely contribute to my growth as a person. In order for quality work to be accomplished, I believe one must leave time to relax and have fun. Thanks for reminding me that there is time for both.

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Introduction / Review of Literature

Whole body vibration (WBV) platforms are used extensively in sport/exercise training (Delecluse, Roelants, & Verschueren, 2003), geriatrics (Iwamoto, Takedo, Sato and Uzawa, 2005), and rehabilitation (Rittweger, Just, Kautzsch, Reeg, & Felsenberg, 2002) programs. Training has been

reported to increase strength and performance gains in lower extremity muscles (Lamont, Bemben, Bemben, Cramer, Shehab, & Anderson, 2007; Roelants, Delecluse, Goris, &

Verschueren, 2004a). Mechanical WBV platforms are commercially available in two different designs (Figure 1). The first

design features a teeter totter like motion with identical reciprocating displacements on either side of the fulcrum and the second design utilizes a stimulus with uniform vertical displacements. WBV stimulus is fundamentally set by two specific mechanical parameters; frequency and amplitude. Frequency is defined as the number of cycles that the platform vibrates per second and is typically set between 25 – 45 Hz. The second component of the WBV stimulus is the selected vertical displacement in millimeters that the platform deflects per oscillation, and is referred to as the amplitude of the vibration.

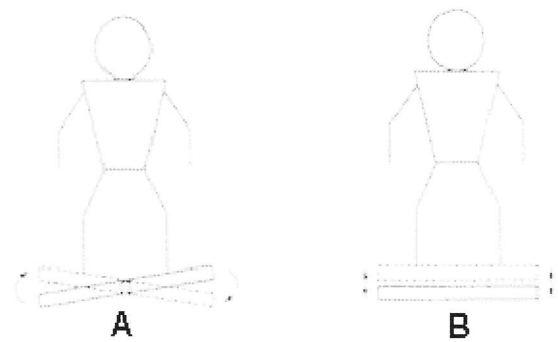


Figure 1 - Platform Types - A) oscillates with reciprocating displacements on both sides of a fulcrum; (B) strictly vertical oscillations (Cardinale & Wakeling, 2005)

The physiological principal behind WBV has been that mechanical vibration is transmitted to the muscles of the body and elicits a reflex muscle contraction similar to the tonic vibration reflex (TVR) (Hagbarth & Eklund, 1966).

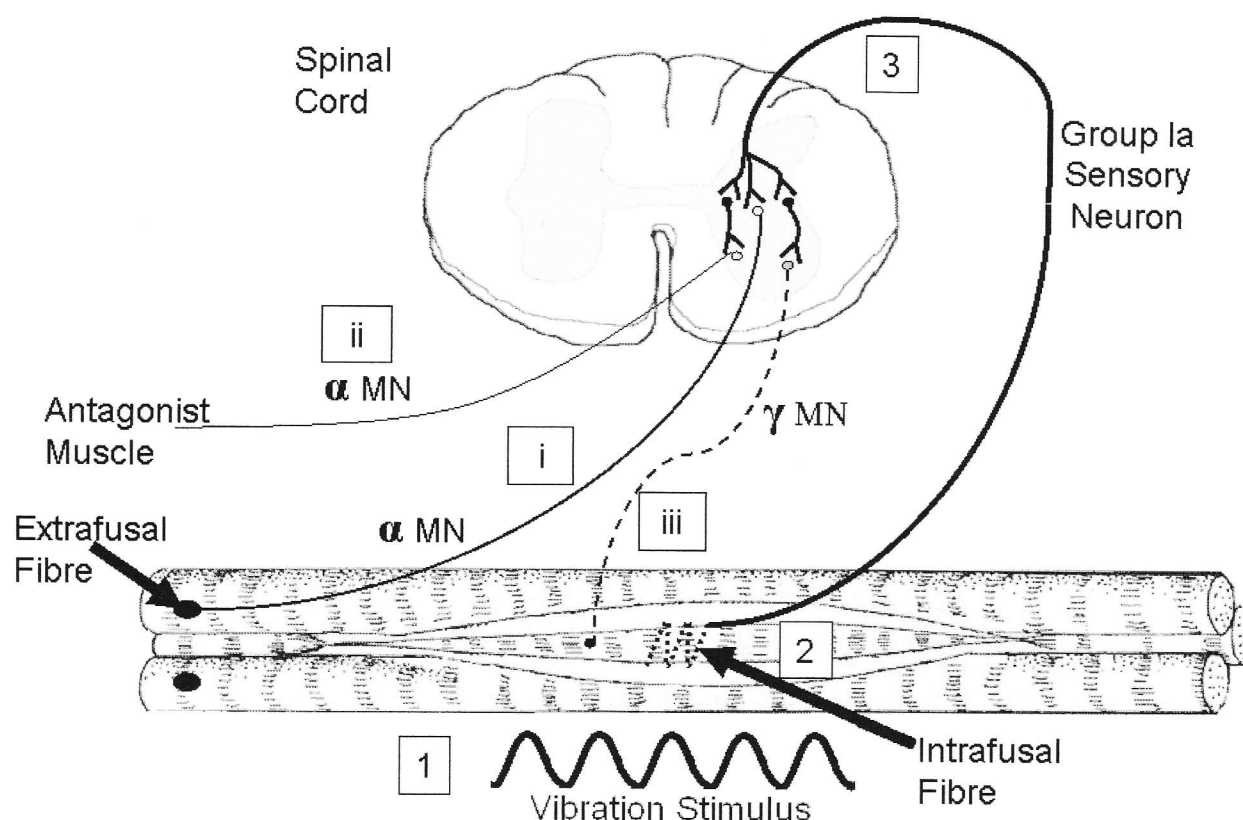


Figure 2 – Tonic Vibration Reflex (Hazell, Jakobi, & Kenno, 2007)

As illustrated in Figure 2, a vibration stimulus from a WBV platform generates short, rapid changes in extrafusal muscle fiber length that are detected by the intrafusal muscles spindles which transmit a signal via Ia sensory neurons to the spinal cord. Once this signal reaches the spinal cord, Ia sensory neurons can : (i) use a mono-synaptic projection (direct) to excite an alpha motor neuron (α MN) that will stimulate a reflexive muscle contraction in the extrafusal muscle fibers of the same muscle, (ii) use

a poly-synaptic projection to inhibit an alpha motor neuron which will prevent antagonist muscle activity, (iii) or use another poly-synaptic projection to activate a gamma motor neuron that will cause the intrafusal muscle fibers of the agonist muscle to reset and maintain their sensitivity to further vibration perturbations (Hagbarth & Eklund, 1966).

Increases in muscle activity have been theorized to be the result of activation of the TVR (Hazell, Jakobi, & Kenno, 2007). However, a more recent study on the neuromuscular response of the soleus to WBV suggests that vibration stimulus does not enhance spinal reflex excitability, but rather depresses it along with the H-reflex (Scherer, Jakobi, & Kenno, 2008). Though the physiological mechanism behind the reported gains resulting from WBV has been questioned (Scherer et al., 2008), WBV training with squatting exercise still reportedly enhances knee extensor strength (Delecluse et al., 2003), rate of leg force development (Lamont et al., 2007), and vertical jump performance (Torvinen et al., 2002a), at given ranges of vibration settings. The frequency and amplitude of vibration, duration of exposure and the posture adopted during WBV are all factors that need to be considered when prescribing WBV, as the interaction of these factors determines the magnitude of the load on the specified muscles (Crewther, Cronin & Keogh, 2004).

Bosco, Colli, Intorini, Cardinale, Tsarpela, Madella et al. (1999b), investigated the effects of WBV on leg skeletal muscle performance of national level female volleyball players. Subjects were randomly assigned to a control (no vibration) group and an experimental (vibration) group. WBV exposure (Galileo 2000) was set at 26 Hz, with 10 millimeters (mm) amplitude, for 10 exposures of 60 seconds (s) duration, with 60 s rest in between each treatment. Subjects were tested on a sliding dynamic leg press prior

to, and following the vibration exposure. Significant enhancements were reported for average velocity, average force, and average power following exposure to vibration. They suggested that the physiological improvements were a result of WBV enhancements in the pathways of working skeletal muscles.

Torvinen and colleagues conducted a series of acute experiments with increasing WBV stimulus while subjects performed 6 functional performance tasks. In the first experiment, WBV stimulus was increased 5 Hz every minute (15 – 30 Hz), for 4 minutes at a constant amplitude (10mm), and they reported significant increases in isometric extension strength of the lower extremities, jump height, and body balance (Torvinen et al., 2002a). Their second study followed the same protocol, but with increased frequency (25 – 40 Hz), and a lower amplitude (2 mm). No improvements in functional performance were reported (Torvinen et al., 2002b). In the third experiment, frequency and amplitude of vibration training was extended to 3 – 5 times per week for 2 – 4 months, and they reported a statistically significant increase in jump height and isometric knee extension strength when compared to the control group (Torvinen et al., 2002c). These results collectively suggested that frequency, amplitude and duration of exposure to WBV can affect training results, and that dynamic movements may aid in performance gains seen with WBV.

In 2003, Torvinen et al. investigated the effect of WBV on bone, muscle performance and body balance in a randomized study. WBV was set at ascending frequencies from 25 – 45 Hz, with a 2 mm amplitude, 4 min / day, and 3 – 5 days / week. They reported a 7.8% increase in vertical jump height, but no effect on the

isometric extension strength of the lower extremities. This study further confirmed the beneficial effects of WBV training on lower limb skeletal muscle performance.

While the majority of the WBV literature reports positive results for WBV training, there are also reports that do not suggest that WBV training enhances performance. de Ruiters, Vaan Raak, Schilperoort, Hollander, & de Haan (2003) examined how WBV squat training effects vertical jump, sprint time, and agility performance measures. With a WBV platform set at 30 Hz with an 8 mm amplitude subjects performed 5 sets of one minute static squats, 3 times per week for 11 weeks, but no benefits were reported. Cochrane, Legg, and Hooker (2004) also placed subjects in 5 different static squat positions on a WBV platform set at 26 Hz and 11 mm. After a total of 9 exposures in each position, no improvement in vertical jump, sprint time, or agility tests were reported. These data again suggest that the platform parameters such as frequency, amplitude, duration of exposure, and exercise protocol can all affect the results of WBV as a training modality.

The effectiveness of WBV training has been compared to traditional resistance training protocols. Delecluse et al. (2003) placed subjects in various squatting positions on a WBV platform at 35 – 40 Hz (frequency) and 2.5 – 5 mm (amplitude), and after 5 weeks of training, the WBV trained subjects experienced ~2% greater gains in isometric and dynamic strength. The WBV group also experienced a 7.6% increase in jumping ability compared to no increase in jumping ability for the traditional resistance training group. Similarly, Roelants et al., (2004) compared the effects of 24 weeks of unloaded static and dynamic WBV platform squats on knee extensor strength, to a standard fitness training protocol. The experiment protocol involved increasing duration of

vibration exposure per session (from 3 – 20 minutes), number of different exercises per muscle group (1 to 3), amplitude (2.5 to 5 mm), frequency (from 35 to 45 Hz) and shortened the rest between sets (from 60 to 5 s). The changes in knee extensor strength experienced after WBV training were comparable to strength increases following a standard fitness training program consisting of cardiovascular resistance training. Additionally, Lamont et al. (2007) investigated the effects of 6 weeks periodized squat training with and without WBV. Subjects in the vibration group were exposed to an acute, low vibration stimulus prior to the training program (week 0), mid training (week 3), and post training, (week 7) to monitor possible adaptations resulting in an increased responsiveness to acute vibration exposure. Significant differences between the vibration and non-vibration group from week 1 to week 3 under both jumping conditions (depth jumps and squat jumps) were observed. From week 0 to 7 both groups showed significant increases for the 1RM squat and rate of force development when compared to the control group. Experimenters found trends favoring the addition of vibration training to resistance training.

Collectively the above studies (Delecluse et al. 2003, Roelants et al. 2004, and Lamont et al. 2007) demonstrate that WBV training results in muscle strength when compared to no vibration and that vibration training may compliment and/or produce comparable results to traditional exercise training programs. While some results from WBV studies do not demonstrate benefits of vibration stimulus, it is apparent that different combinations of frequency, amplitude, and duration (Torvinen et al. 2003) contribute to their varying overall effectiveness.

Much of the research to date has focused on lower body skeletal muscles utilizing WBV platforms to test the effectiveness of a vibration stimulus. However, a few studies have been conducted using other devices such as vibrating dumbbells and cable apparatus' to stimulate the upper body. Issurin, Liebermann, & Tenenbaum, (1994), compared arm strength training with a vibrating cable attached to a weight stack to standard weight training 3 times a week for a period of 3 weeks (see Figure 3).

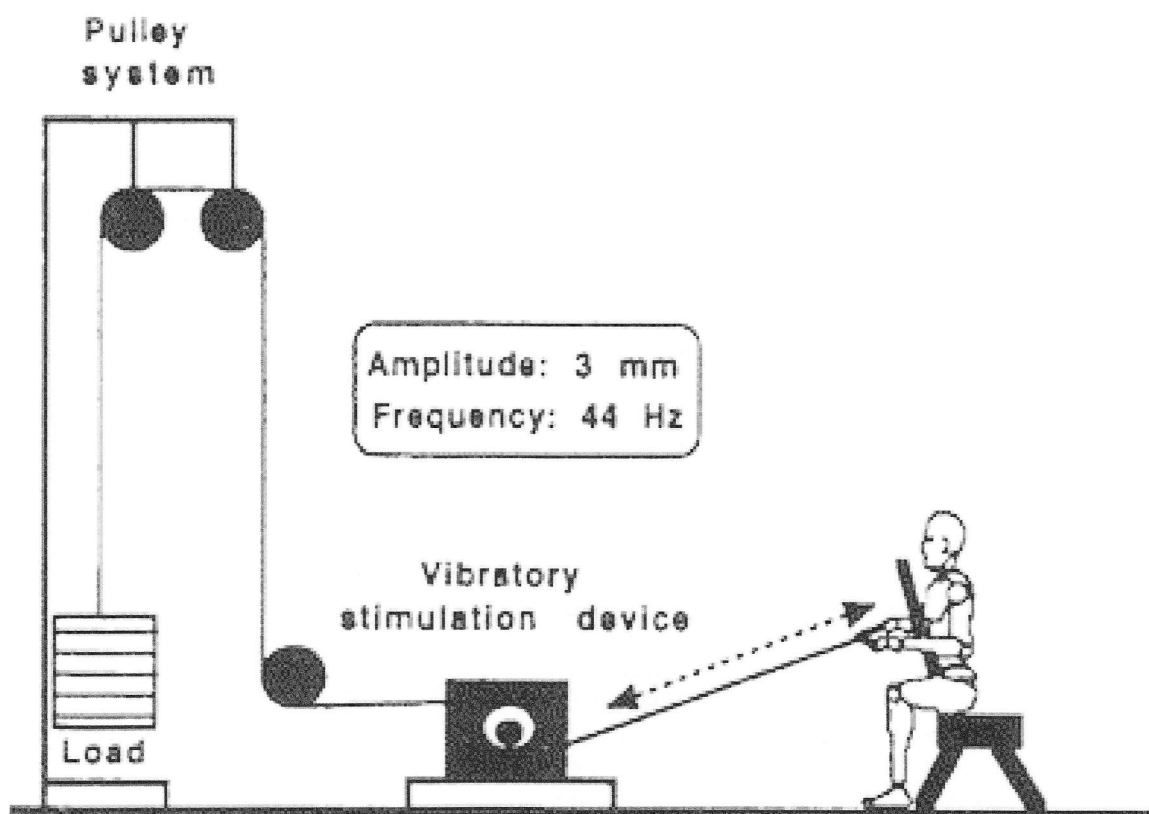


Figure 3 – Vibrating Cable Device used to stimulate arm flexors.
Issurin et al. (1994 and 1999)

They used a frequency of 44 Hz with 3 mm amplitude and found an average increase of 49.8% in 1 Repetition Maximum (1-RM) which was significantly greater than the 16.1% increase experienced by the non-vibration group. These results demonstrate that the arm flexors respond to vibration stimulus similarly to the knee extensors and flexors with applied vibratory stimulus.

Issurin and Tenenbaum, (1999), also examined the acute effect of arm flexor training using the same vibrating cable apparatus (see Figure 3) on arm strength of male amateur and elite level power lifters. Subjects performed 2 – 3 sets of rapid biceps contractions with a load between 65 – 76% of their 1-RM. Subjects demonstrated increases in explosive strength of 10.4% and 10.2% for maximal and mean power in the elite group, and 7.9% and 10.7% in the amateur group. However strength gains were only temporary as the lasting effects of these increases were not maintained. Collectively, the studies done by Issurin et al. (1994; 1999) were able to show evidence of performance gains in the upper extremity muscles using a vibrating cable assembly. The above studies reported performance enhancements (Bosco et al, 1999b) or effectively compared their results to conventional forms of training (Delecluse et al, 2003), but did not quantify how or if specific muscles were influenced by the vibration stimulus.

In an attempt to determine how WBV influences muscles, Cardinale and Lim, (2003), were the first to analyze electromyography (EMG) responses of vastus lateralis (VL) muscle at a variety of frequencies (30, 40, 50 Hz). Subjects performed a static half squat on a WBV platform set at 10 mm amplitude, and found greater average EMG from the VL at all frequencies compared to the no vibration condition (see Figure 4).

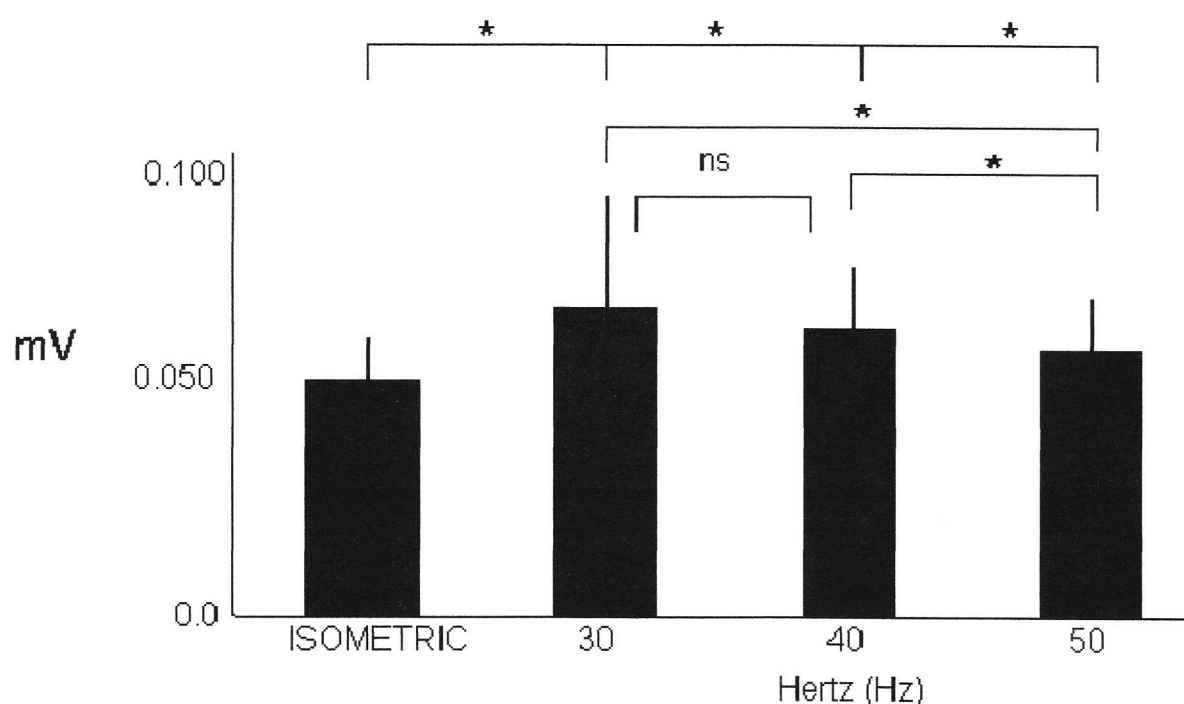


Figure 4 - Electromyography root mean square (EMG_{RMS}) values recorded from the vastus lateralis muscle, with no vibration compared to varying frequencies, during an isometric semi-squat (100° knee angle) on a WBV platform. The error bars indicate standard deviation. * $p < 0.05$; ns=not significant; mV=millivolts. Adapted from Cardinale & Lim, 2003.

These EMG recordings support utilization of the half squat position on a WBV platform as effective for triggering VL stimulation. Cardinale and Lim, (2003), also suggested that EMG analysis of individual muscle groups might be an effective way to individualize vibration treatment, and assess muscle responsiveness to different frequencies.

As the literature has shown, investigators have used multiple frequencies and amplitudes to achieve results in the squat position. Hazell et al. (2007), used EMG analysis to determine an optimal frequency and amplitude for squatting on a WBV platform. Subjects performed isometric semi-squats and unloaded dynamic squats with WBV set at randomly assigned frequencies ranging from 25 – 45 Hz at either 2 or 4 mm. EMG muscle activity recorded from the vastus lateralis (VL) and biceps femoris

(BF), demonstrated a significant increase in muscle activity as compared to a no vibration condition (Figure 5) (VL - 0.6 – 8.7%MVE; BF - 0.3 – 2.0%MVE) (Figure 5).

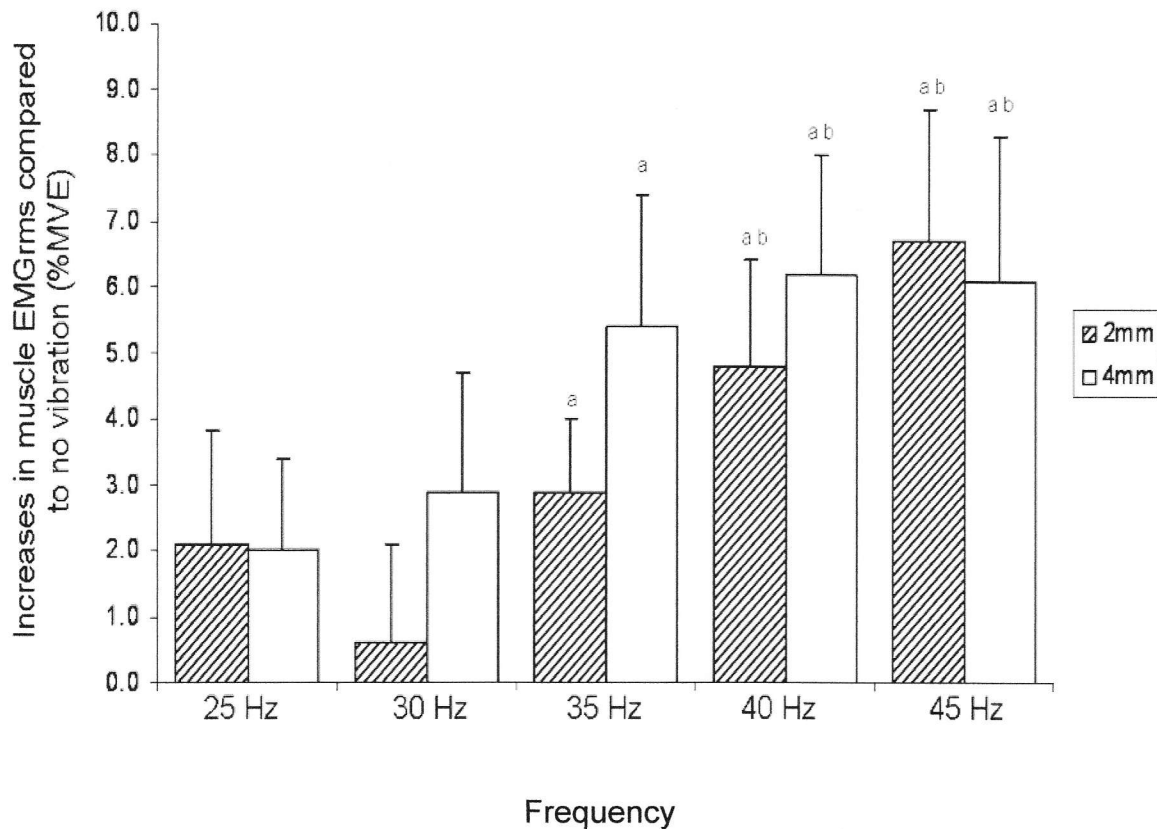


Figure 5 – Increases in vastus lateralis EMG_{RMS} activity with whole body vibration compared to no vibration during an isometric semi-squat.

Values are mean \pm SE.

^a – significantly greater than no vibration ($p < 0.05$)

^b – significantly greater than 25 and 30 Hz ($p < 0.05$)

Overall, the higher WBV amplitude (4 mm) and frequencies (35, 40, 45Hz) resulted in the greatest increases in dynamic EMG muscle activity (Hazell et al. 2007).

WBV performance (Torvin et al, 2003) and EMG (Cardinale & Lim 2003) studies support the use of the squat position for training leg strength on vibrating exercise platforms. As previously stated, the majority of the literature has studied effects of WBV on leg muscles with few studies on the effects of vibratory stimulus on upper body

muscles. Interestingly, Hazell et al. (2007), who reported that the higher frequencies (35-45Hz) and amplitude increased EMG optimally for the lower body, also placed EMG electrodes on the triceps brachii (TB) and biceps brachii (BB) while subjects squatted on the WBV platform. They reported little to no vibratory effect on the resulting EMG activity of the BB (0 – 0.8%MVE) and TB (0.2 – 1.0%MVE). They theorized that the reason for the lack of EMG activation of the upper body muscles while in the squat position was distance from the WBV platform

Bosco, Cardinale, & Tsarpela (1999a) were the first to use EMG recordings to measure muscle activity of the arm flexors for subjects using handheld vibrating weights (Figure 6). Subjects lifting vibrating dumbbells (30 Hz and 6 mm) equal to 5% of their body mass experienced a statistically significant improvement (13%) in average mechanical power. Furthermore, analysis of EMG_{rms} recorded during the treatment showed statistically significant enhancements when compared to the pre-vibration values for EMG_{rms} in the arm flexors. These results demonstrate that upper body

musculature is responsive to vibration stimulus and that EMG_{rms} recordings can be used to measure the effects of vibration training on upper body skeletal muscle.

Since there have been positive results reported for the use of WBV platforms on the lower body, clinicians have made the assumption that upper

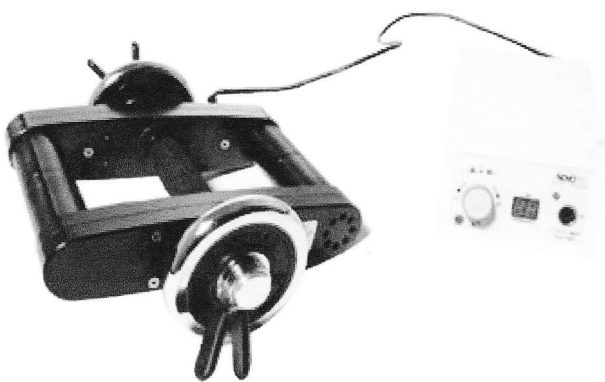


Figure 6 – Handheld vibrating dumbbells
www.squashplayer.co.uk/.../galileo_dumbbell.htm

body muscle groups were similarly affected by stimulus from a vibrating platform. However, Hazell et al. (2007), reported that the TB and BB were not effectively stimulated while subjects squatted on a WBV platform. Issurin and colleagues (1994; 1999), along with Bosco et al. (1999a) reported that the arm flexor muscles showed improvements in performance and an increase in EMG_{RMS}. Still, the upper body skeletal muscles as a group remain largely unaffected by vibration with each of these experimental set ups and an ideal position is still unknown.

The push up for example is normally performed to increase strength, or endurance of muscles that span upper extremity joints (Beach, Howarth, & Callaghan, 2008). The standard push up primarily targets the pectoralis major (PM) and triceps brachii (TB), but it also activates several other upper extremity and trunk muscles as indicated by EMG studies, and has been used to measure the strength and endurance of the upper body (Cogley, Archambault, Fibeger, Koverman, Youdas, and Hollman, 2005). In fact, most biomechanical investigations that have focused on upper extremity muscles and joints have done so through the study of the push up exercise (Gouvali & Boudolos, 2005, Cogley et al. 2005, Beach et al. 2008). Placing the hands on a WBV platform while performing push ups will improve proximity of the larger upper body skeletal muscles to the stimulus, which may lead to increased transmissibility and ultimately greater increases in EMG activity of selected muscle groups.

To our knowledge, the only data collected for subjects performing push ups on a WBV platform was found in a published abstract done by Terra, Teixeira, Leite, Pereira, & Gomes, (2007). This performance study compared the maximum number of self paced push ups performed before and after acute vibration exposures to random

settings of frequency (30 Hz – 50 Hz) and amplitude (2 – 6 mm); none of the frequency and amplitude combinations had a significant effect on subject's maximum push up capability. Terra et al. (2007) did not record EMG activity from any of the muscles associated with performing push ups at any of the experimental frequencies or amplitudes.

Therefore, considering the insignificant changes in EMG activity of the TB and BB in the squat position during WBV (Hazel et al., 2007) and the increases in bicep EMG activity reported with vibrating dumbbells (Bosco et al. 1999), it is conceivable that direct contact may enhance EMG activity of skeletal muscles in the upper body while performing push ups on a vibrating platform. The main objective of this study was to determine the optimal vibrating platform frequency and amplitude to stimulate increases in EMG muscle activity in the pectoralis major, latissimus dorsi, triceps brachii, and biceps brachii during pushups.

Methods

Fifteen recreationally trained male subjects were recruited from the university and surrounding community. Criteria for exclusion included pain or dysfunction that substantially limited ability to perform the standard push up exercise. In accordance with manufacturers recommended contraindications to vibration training additional exclusion criteria consisted of diagnosis of diabetes, epilepsy, gallstones, kidney stones, acute inflammations, joint problems, cardiovascular diseases, joint implants, recent thrombosis, and back problems such as hernia, tumors, recent operative wounds, or intense migraines. All subjects were required to sign written consent (see Appendix A) and Par Q (see Appendix B) forms.

Initially, each subject came in for a familiarization protocol (Session 1) during which, they were informed of the experimental protocol. Session 1 lasted 15 – 30 minutes where age, height, total body weight, and upper body weight (UBW) were measured. UBW is the weight supported by hands in a standard push up position. Measurement of upper body weight was made on a force platform (AMTI model – OR6 – 6 – 1000). Body position during UBW determination was identical to the up phase of the standard push up exercise which was executed on the platform during the practice session and data collection. The distance between left and right acromioclavicular joints was also measured for each subject so it could be identified on the platform for consistent hand position placement while performing pushups during familiarization and data collection.

Subjects were then introduced to the vertical WBV stimulus (WAVE platform, Figure 7) used during the experiment. To familiarize subjects with WBV, each subject



Figure 7 – The WAVE Platform,
Windsor, Ontario, Canada
<http://www.wavexercise.com/index.html>

was asked to first stand on the vibration platform with feet shoulder width apart, and a knee angle between 110-130°. The vibration platform was turned on at a frequency of 25 Hz and set to an amplitude of 2 mm for 30 sec to allow each subject to experience the sensation of the vibration stimulus. Following a brief rest period of 30 seconds, the frequency and amplitude were increased to allow the subject to experience the range of vibration stimuli the platform can produce. Following this introduction protocol, subjects placed their hands on the platform and low level and higher levels of

vibration, identical to that used while upright on the platform, were administered for upper body accommodation.

Subjects were then provided with a demonstration of the proper technique to perform a standard push up. All movements were completed from a standardized position with the feet together, and hands shoulder width apart. A piece of masking tape was placed on the platform ahead of time to represent the measured space between right and left acromioclavicular joints. The index finger of each hand was placed at the outside of each end of the tape, and subjects were instructed to keep their fingers in a comfortable position with no more than 1.5 cm between each finger.

Participant's feet were also elevated on a separate platform (custom build; University of Windsor) to keep their feet at the level of the WAVE platform in order to replicate push ups performed on the ground level. Foot position on this surface was marked with masking tape once subjects became comfortable with the exercise. The platform was turned on once again at 25 Hz and 2 mm (low) while the subject performed push ups with the sensation of vibration stimulus. Frequency and amplitude were once again increased to allow the subject to experience the sensation of vibration stimuli while performing push ups.

An auditory stimulus was set to sound every 1.25 seconds to alert the participant to execute the up and down phase for the seven push ups (see Figure 8). Subjects were allowed to practice as many times as needed during Session 1 in order to perform push ups on the platform correctly and comfortably with the auditory cue. No subject performed more than 10 total push ups during Session 1.

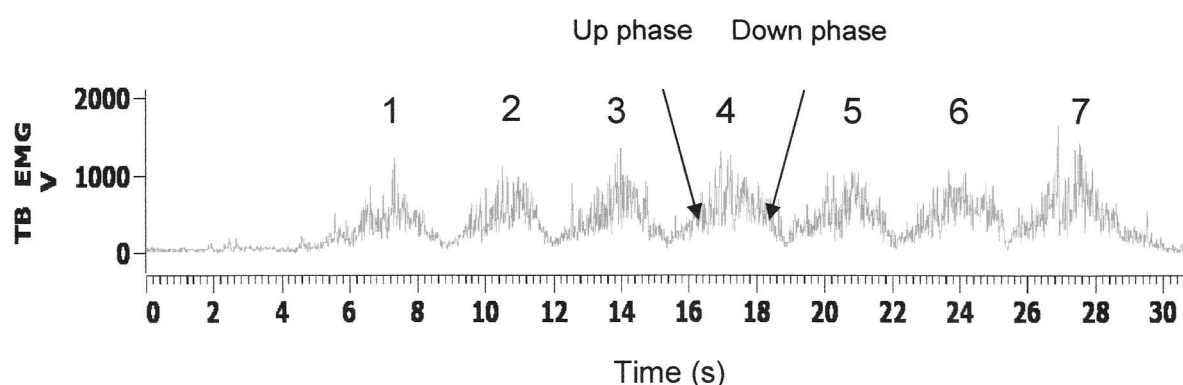


Figure 8 – Up and down phase for triceps brachii EMG activity during 7 push ups.

To ensure that subjects had enough time to recover from Session 1, a minimum of 48 hrs was required before returning to the lab for Session 2. Before data collection, the WAVE platform was calibrated to support each subject's UBW. A goniometer and

surface electrodes were set up as depicted in Figure 9 on the subject's non-dominant side.

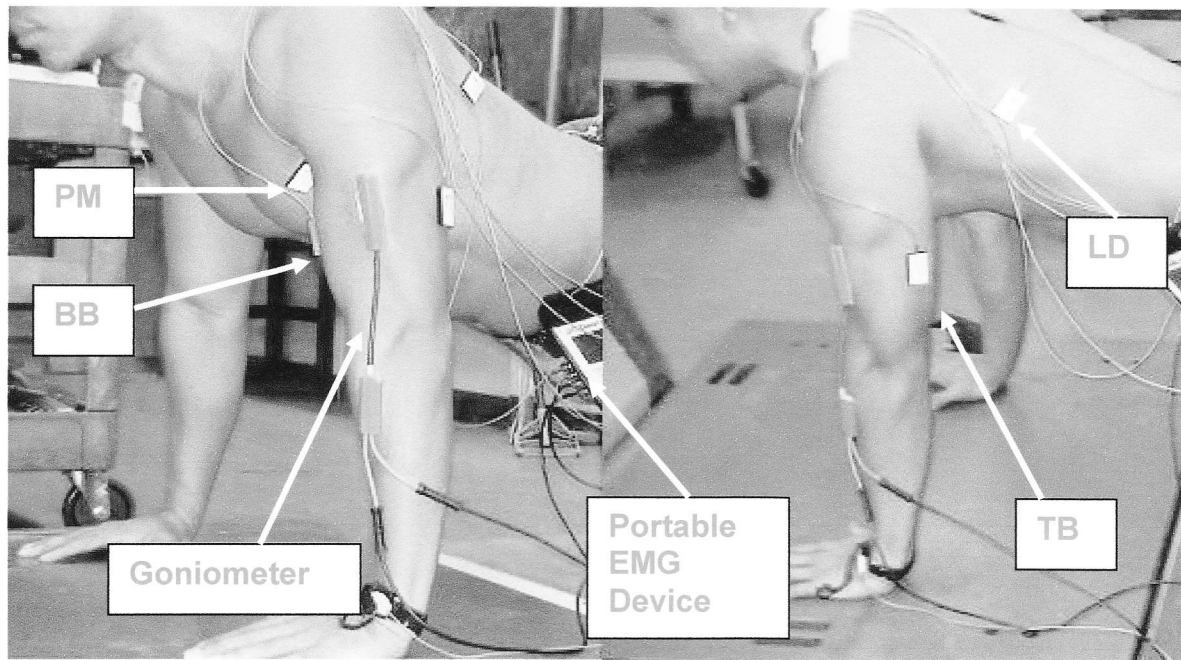


Figure 9 – Electrode and goniometer placement on pectoralis major (PM), biceps brachii (BB), triceps brachii (TB), and latissimus dorsi (LD).

Surface EMG electrodes (Biometrics DataLog) were placed on the primary agonist muscle groups; the pectoralis major (PM) and triceps brachii (TB) (Cogley et al., 2005), as well as opposing muscle groups; the latissimus dorsi (LD), and biceps brachii (BB). The LD was chosen as the opposing muscle for the PM as it has been used in previous surface EMG studies (Lehman et al. 2006) utilizing surface electrodes. The BB brachii are the antagonist to the TB.

In preparation for electrode placement, hair was shaved from the electrode placement area (see Figure 9), and the skin surface was also wiped with alcohol to reduce impedance associated with skin oils and hair. One surface electrode was placed parallel to the muscle fibers on the PM, anterior to the axillary fold, in direct

vertical line with the coracoid process. Electrodes were also placed parallel to the fibers on the LD (on the posterior axillary fold, directly lateral to the inferior tip of the scapula). The TB surface electrode was placed on the distal one third of the arm, directly in line with the lateral epicondyle. Lastly, a surface electrode was placed in parallel with the muscle fibers of the BB (on the middle one third of the arm, in the center of the muscle belly) (Geiringer, 1994). Joint angle was measured using a goniometer placed at the elbow joint (see Figure 9) which helped identify the beginning and end of each push up.

Table 1 - Experimental Conditions

Freq (Hz)	Amp (mm)
25	2
25	4
35	2
35	4
45	2
45	4
No Vibration	

Once all the electrodes were positioned and wires secured to the skin with tape, each subject was instructed to lay flat on their stomach for a one minute noise trial. The noise trial allowed determination of the amount of baseline interference in the laboratory, so it could be subtracted from the EMG recordings for each experimental condition during data processing (Labview software). Following the noise trial, subjects performed

3 maximal voluntary exertions (MVE) of the PM, LD, TB, and BB against manual resistance from the experimenter. The MVE for the PM was performed with the subject seated with back supported and with shoulder horizontally abducted perpendicular to the spine with the elbow at 90° and forearm in the standard push up position while the subject performed a maximal anterior press exertion. The MVE was measured in the LD with the elbow extended, and arm adducted 30° and internally rotated while the subject performed a maximum shoulder extension against manual resistance. For the TB the MVE was measured with the subject standing with the elbow flexed to 90° and a

maximal elbow extension against manual resistance. The MVE for the BB followed the same protocol as TB, except flexion contraction was performed against manual resistance. All MVE were isometric and performed three times to ensure that maximal activity was attained. These MVE recordings were used to normalize EMG data for processing. Techniques for measuring MVE values were consistent with prior studies (Hazell et al., 2007; Lehman et al. 2006). One-minute rest between each MVE occurred to ensure no fatigue effects. Following the completion of the last MVE seven sets of seven standard push ups randomized across the trials (no vibration (NV), or with vibration of 2 (low) or 4 mm (high) at 25, 35 or 45 Hz) were executed (Table 1)). Between each experimental condition, subjects were given 7 minutes of rest.

Following each experimental condition, ratings of perceived exertion were recorded on a 10 point Borg Scale (see Appendix C). During this Session, heart rate (HR) was recorded with monitors attached with adjustable straps below the xiphoid process to provide an additional measure of exertion after each experimental condition.

Data Processing

The EMG signal was post processed using customized software (Labview, National Instruments, Austin, Tex.). Data points from the first and last push up in each set of seven were affected by initial position adjustments and premature completion of the last push up. Thus, the middle 5 push ups were analyzed (see Figure 10).

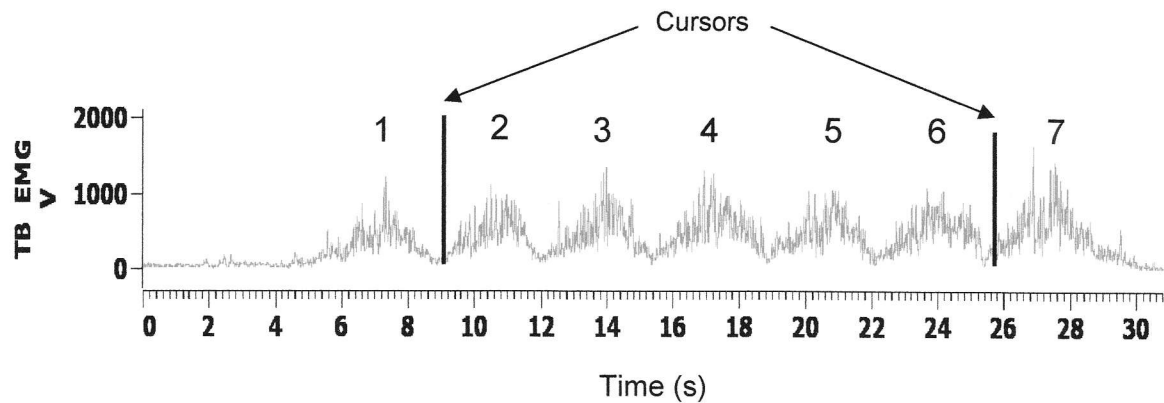


Figure 10 – Cursor placement during analysis of triceps brachii EMG activity for 7 push ups.

The EMG signal was sampled at 5000 Hz and was pre amplified by a gain of 1000 (DataLOG, Biometrics Ltd., Gwent, UK). The interference EMG for both periods was dual passed 6th order Butterworth filtered between 100 and 450 Hz, which removed any of the noise from the surrounding environment including that of the WBV platform itself (Hazell, et al., 2007). The data was then full-wave rectified and smoothed with a low pass filter at 1.5 Hz. Within the Labview software, the noise was then subtracted and maximum values for EMG_{RMS} were extracted and divided by the MVE and multiplied by 100 for normalization. EMG_{RMS} values were based on the percent increase in muscle activity during WBV.

Statistical Analysis

Statistical analysis investigated the effects of the independent variables of muscle and vibration condition on EMG_{RMS} . A 4 x 7 (muscle x condition) repeated measures ANOVA was used to determine the interaction between all 7 conditions (Table 1) as well as the potential interaction of the 4 muscles; pectoralis major, latissimus dorsi, triceps brachii, and biceps brachii, studied. To determine the interaction between each experimental condition and RPE a separate 1 x 7 (RPE x condition) repeated measures test was performed. The interaction between each condition and HR was also determined using a 1x7 (HR x condition) repeated measures ANOVA. A 0.05 α was utilized and post hoc Bonferroni tests were employed for all significant interactions.

To determine the effect of vibration condition (Table 1) on each individual muscle, separate repeated measures ANOVAs were performed. Comparison-wise type I error was thus introduced to the data for each separate analysis. Bonferroni adjustments were used to calculate the adjusted probability α of comparison-wise type I error from the desired probability α of the original 4 x 7 repeated measures ANOVA. The calculation guaranteed that the use of the adjusted α ($\alpha = 0.0125$) in pairwise comparisons from 4 separate repeated measures ANOVAs, kept the actual probability α from the 4 x 7 repeated measures ANOVA, and not higher than the desired level.

Results

According to the Par Q forms (Appendix B) which were signed by each subject, no subject had any history of injury or health condition that would serve as a contraindication to participation in the investigation. Previously, Cogley et al. (2005) reported individuals performing push ups supported 66.4% of their total body weight. Subjects stood with two feet on the force plate in order to measure total body weight (age, 24 years; height 175 ± 0.5 cm; weight, 170 ± 0.5 lbs), and then were asked to place both hands on the force plate (AMTI model – OR6 – 6 – 1000) in a standard push up position to determine the percentage of total body weight being supported by each subject while performing push ups in this experiment. The percentage of BW that subjects supported in the experiment was calculated to be 68%.

The 4x 7 (muscle x condition) interaction and main effect for condition was non-significant, but there was a main effect for muscle ($p > 0.0001$). Muscle activity for the agonist muscle groups (PM and TB) was significantly higher than that of their opposing muscle groups (LD and BB). Activity in the PM was $45.8 \pm 3.4\%$ MVE, and in the TB was $42.5 \pm 3.4\%$ MVE. These values were significantly greater than the LD ($12.0 \pm 3.4\%$ MVE) and BB ($7.0 \pm 3.4\%$ MVE) (Figure 11).

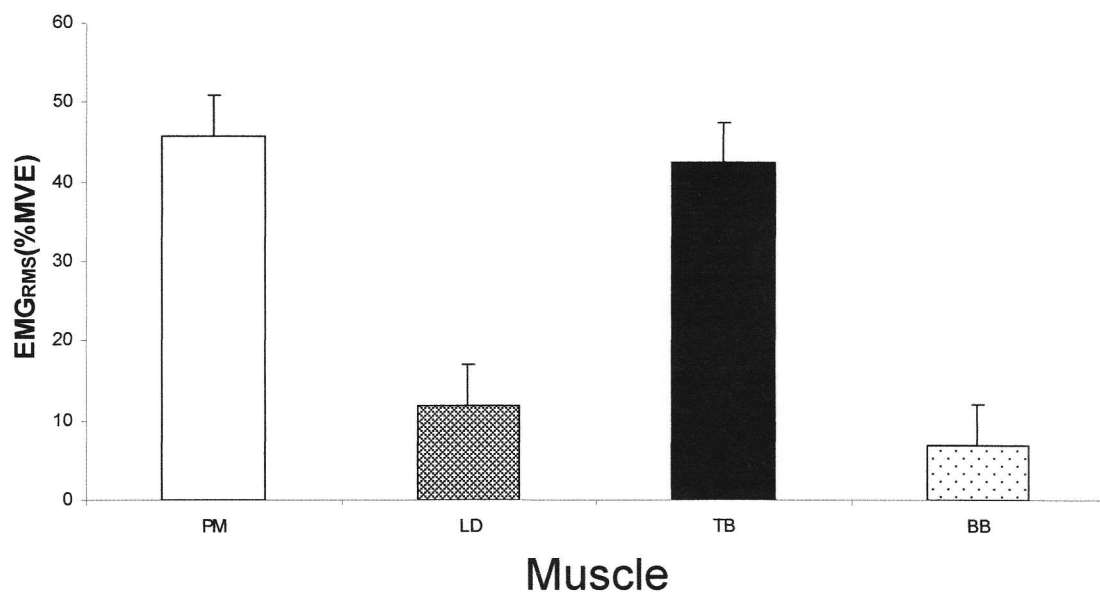


Figure 11 – EMG_{RMS} activity for each upper body muscle during push up. Pectoralis major (PM) and triceps brachii (TB) are significantly greater than LD and BB ($p \leq 0.05$). Number of subjects (n) = 15

To determine whether there was an independent effect of WBV on the 4 muscles of interest separate 1 x 7 (muscle x condition) repeated measures ANOVAs were conducted. For the PM, LD, TB, and BB with a Bonferroni adjusted α (0.0125), the only significant increase over NV was seen at the 45 Hz, 4 mm condition in the triceps brachii (TB) and biceps brachii (BB) (Figure 12, c and d). Figures 12a and 12c depict increases at the 45 Hz, 4 mm condition near 50%MVE the primary agonists (PM = 48.9%MVE; TB = 46.7%MVE) but only the triceps were significant at a $p \leq 0.05$ level, and only at the highest frequency, amplitude combination. Overall, the increase in WBV intensity did not augment EMG activity in muscles covering the axial spine.

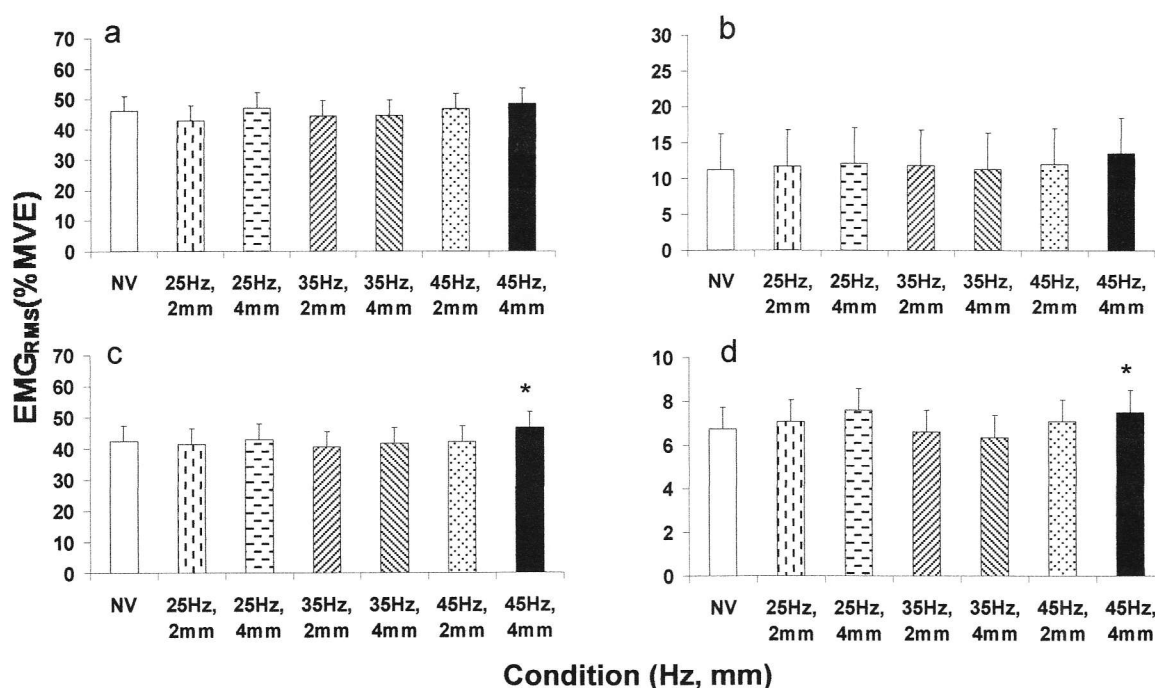


Figure 12: Mean EMGRMS for the a) pectoralis major, b) latissimus dorsi, c) triceps brachii & d) biceps brachii at varying conditions compared to NV. * - significantly greater than no vibration (NV)

Results for ratings of perceived exertion (RPE) indicated that four out of the six vibration conditions were perceived to be more intense than NV (Figure 13). The 45 Hz and 4 mm condition was rated just under 5 (5 = strong) on the 10 point Borg scale and was perceived to be more intense than all conditions other than the 25 Hz and 4 mm condition. The perception of the 25 Hz and 4 mm combination was also perceived to be statistically more intense than the 35 Hz and 2 mm, 25 Hz and 2 mm, and NV conditions which were all rated below 3 on the 10 point Borg scale (2 = weak; 3 = moderate).

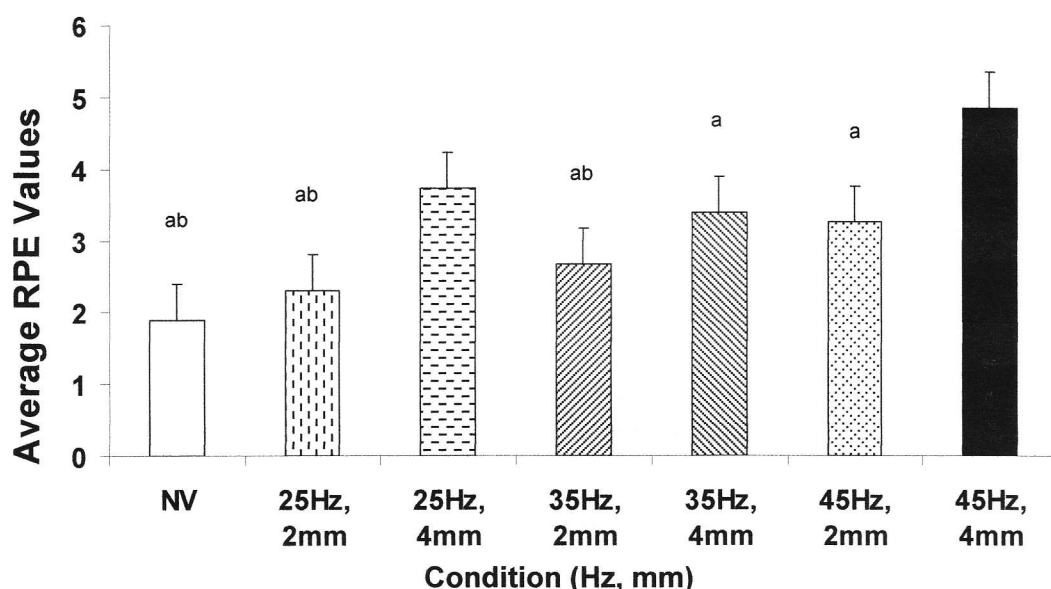


Figure 13 – Average ratings of perceived exertion values on a 10 point Borg Scale. The 45Hz, 4mm condition was perceived to be more intense than all conditions except 25Hz, 4mm. 25Hz, 4mm was perceived to be more intense than no vibration (NV), 25Hz, 2mm, and 35Hz, 4mm.

^a – statistically different from 45Hz, 4mm.

^b – statistically different from 25, 4mm.

HR data could only be recorded from 13 subjects due to equipment failure during testing. Heart rate and RPE did not reflect similar changes in intensity. Overall, the perception was 45 Hz and 4 mm was most intense, but average HR did not differ between conditions (Figure 14).

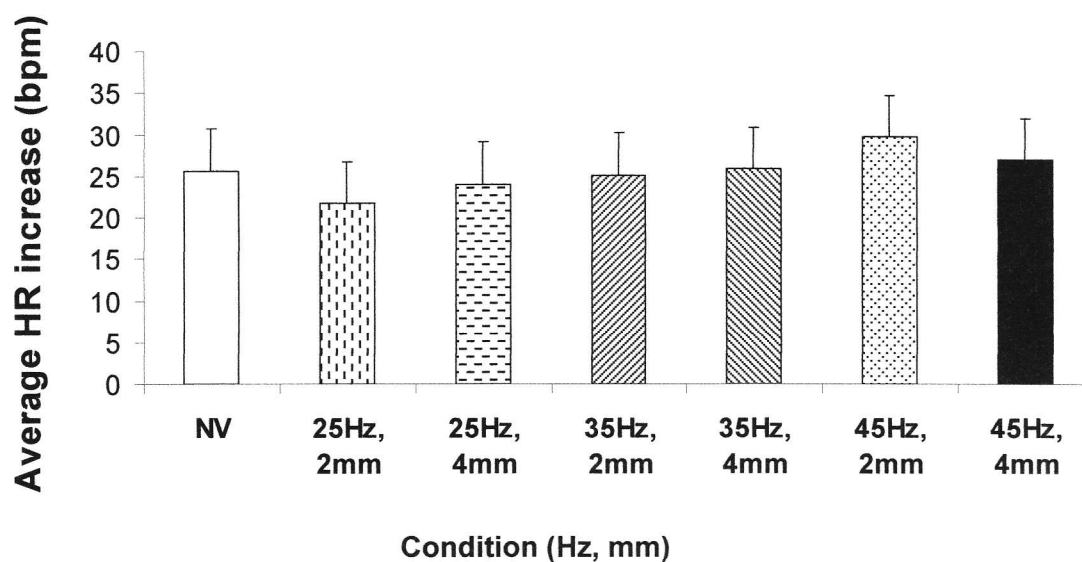


Figure 14: Average HR increases for 13 subjects across all 7 conditions. no statistically significant increases (n) = 13.

Discussion

The present study investigated the effects of direct stimulus from a WBV platform on the EMG activation of muscles in the upper body during dynamic push up exercise. The standard push up primarily activates the pectoralis major (PM) and the triceps brachii (TB) muscle groups. It was anticipated that significant increases in these muscles and their opposing muscle groups (LD and BB) would be observed when exposed to whole body vibration at all vibratory settings. The results from this investigation indicated that the lower frequency, amplitude combinations had no significant effect on any of the primary or opposing muscle groups. While the axial muscles (PM and LD) were unaffected by vibration in this experiment, the appendicular muscles (TB and BB) experienced significant increases at the highest vibration condition.

The current results are similar to those reported by Lehman (2007) who used the push up performed on an unstable surface to determine if surface stability altered muscle activation. He measured surface EMG activity from the PM, LD, TB, rectus abdominis (RA), and external oblique (EO) muscles, for subjects performing push ups on an unstable surface (swiss ball) and hypothesized that the unstable surface and/or varying joint positions, would influence muscle fiber recruitment levels (Lehman, 2007). Similar to our results, Lehman, 2007 reported that the TB was one of the only muscles to experience an increase in average EMG activity. Interestingly, data from the current study as well as Lehman, (2007) demonstrated that the PM, which is considered to be a primary agonist during the push up exercise does not respond significantly to an unstable surface or to the stimulus from a whole body vibration platform.

Cardinale and Lim (2003) initially used EMG recordings as a tool to assess the responsiveness of muscle to WBV stimulus. Hazell, et al. (2007), determined the optimal platform settings (35-45Hz; 4 mm) to stimulate increased EMG_{RMS} activation of muscles in the lower body while in the squatting position but they also reported no significant effects of any combination of frequency and amplitude on TB or BB for subjects in the dynamic squatting position. To improve the transmissibility of vibration stimulus to the upper body and to potentially increase muscle activity in our experiment the hands were placed directly on the vibration platform while subjects performed dynamic push ups.

While closer proximity to the vibration source in the push up position improved resultant EMG_{RMS} activity in the TB and BB, vibration stimulus from the WBV platform was not as effective as the stimulus from the vibrating dumbbells (Bosco et al., 1999a) used in earlier research. Data from the current study demonstrates a possible trend favoring higher parameter settings to achieve significant increases with vibration training. Issurin et al. (1994, 1999) set vibration at 44 Hz and 3mm and reported significant increases in 1RM and explosive strength. More recently, Cochrane and Hawke (2007) used electric powered vibrating dumbbells set at 26Hz and 3mm, in their study investigating the effects of vibration stimulus on strength and power of climbers, but no benefits were reported. While Issurin (1994; 1999) reported positive results in both studies (1994; 1999) with higher parameter settings, Cochrane and Hawke (2007) indicated no identifiable benefits to vibration set at lower parameter settings. EMG muscle activation was not recorded by Issurin (1994; 1999) or Cochrane and Hawke (2007), but results from all three studies reflect the same trend observed in the current

data. Bosco et al. (1999a) reported increases of 200% in EMG activity above baseline values recorded before testing following their study using vibrating dumbbells set at 30Hz, 6 mm. This EMG data contributed to our investigation of the push up position to improve proximity to the WBV platform to achieve increases in upper body muscle activity. Our results indicate that a high combination of frequency and amplitude coupled with close proximity is advantageous for producing significant localized increases in muscle activity when performing push ups with hands placed directly on a WBV platform, but we suspect that other factors affect overall effectiveness of incoming vibration stimulus.

One factor that may have contributed to our results is muscle stiffness. Muscle stiffness increases with muscle activation as a result of the increased number of activated cross-bridges (Ma & Zahalak., 1985; Lee, Rogers, & Granata., 2006), and it has been reported that increased muscle stiffness leads to an increase in vibration transmission through the hand-arm system (Tudor, 1996; Pyykkö, Färkkilä, Toivanen, Korhonen, and Hvärinen., 1976). Pyykkö et al, 1976 attached accelerometers to the wrist, elbow and upper arm, and demonstrated that vibration increased through the hand and arm with increased grip strength in their experiment of vibration from a handle at frequencies ranging from 20 to 630Hz. Feltham, van Dieën, Coppieters and Hodges (2006) further reported that a vibration stimulus at 3 frequency settings (45, 50, 55Hz) increases muscular co-contraction of agonist and antagonist muscles which contributes to joint stability and ultimately vibration transfer (Feltham et al, 2006). This may help to explain the increase in muscle activity of both the TB and BB during the pushup, but does not explain the lack of activation in the PM and LD.

Another key factor that may have affected the overall transmissibility of the vibration stimulus to the upper body in our experiment is the number of joints (wrist, elbow, shoulder) which separated the targeted muscles from the vibration platform. Previously, for subjects standing erect on a WBV platform, transmissibility from the ground to the hip and spine was reportedly greater than 100% due to tissue resonance (Rubin, Pope, Fritton, Magnusson, Hansson, & McLeod 2003). Rubin et al. (2003), placed transcutaneous pins in the spinous process of L4 and greater trochanter of 6 subjects who stood on a WBV platform and reported that transmissibility to the hip and spine decreased to 80% at frequencies of 25Hz or greater during erect standing, and a further decrease to 60% with bent knee posture. Sörensson and Burström (1997) further studied the transmission of vibration energy to three selected points along the hand and arm (knuckle, wrist and elbow) for subjects holding on to a vibrating handle. They reported greater sinusoidal vibration transmissibility in their study, especially at higher frequencies but concluded that vibration decreased as the distance from the vibration stimulus increased. Our current data indicate similar results with the TB and BB responding to vibration at 45Hz, 4 mm, but not at the lower conditions. These data (Sörensson & Burström 1997; Rubin et al., 2003) suggest that while performing push ups, a large portion of the vibration stimulus may have been attenuated when passing through the wrist and elbow joints. Dewangan and Tewari (2008), more recently reported a decrease in vibration transmission through the hand-arm system beginning in the metacarpals and finishing in the acromion. Their data parallel's our current results showing little effects of vibration stimulus in the muscles of the axial skeleton (PM) and this may have been due to the ball and socket joint at the shoulder.

The relationship between agonist and antagonist muscles at the glenohumeral joint (shoulder) is complex since it is dependent on the integrity of the periarticular soft tissues (capsule, ligaments and surrounding muscles) (An and Friedman, 2005). According to Lephart, et al. (1994), the long head of the biceps is one of the muscles responsible for the dynamic stabilization of the shoulder joint, but there are many muscles which guide the shoulder in flexion / extension, adduction/ abduction, and rotation (Basset, Browne, Morrey and An., 1990). Since there are a number of muscles which contribute to the agonist/antagonist relationship at the shoulder, joint stability during push ups may not have been optimal, thereby not maximizing vibration transmissibility to the axial skeleton.. These factors along with data from Sörensson and Burström (1997) and Dewangan and Tewari (2008), may explain why the PM and LD were unaffected by vibration at any setting for frequency and amplitude.

There is however the potential for differences between the upper and lower body muscles with respect to the effects of fatigue on tissue responsiveness and vibration transmission. The conditions in our experiment were randomly assigned for each subject, so each condition would have been experienced by each subject at a different time in the sequence of the 7 conditions. One recent study suggests that studies of this nature should employ experiment designs that include subjects who are tested on multiple days (Armstrong, Nestle, Grinnell, Cole, Van Gilder, Warren et al. (2008). Even when conditions are randomly ordered, Armstrong et al. (2008) submit that these designs may not provide adequate recovery of the motor unit. Due to muscle size this potential fatiguing factor may not have been relevant in the Hazell et al. (2007) experiment, but may have been a factor in the current experiment which challenged the

smaller arm muscles in the upper extremity. The present investigation used a design with at least 7 minutes rest time allotted for each subject following each experiment condition. Prior to commencement of the investigation, a small pilot study (4 subjects) was performed to ensure that recovery time following each condition was adequate based on heart rate (HR). However, after reviewing the HR data collected in the current study, we suspect that HR may not be the best indicator of recovery from WBV, and this could have been a limitation of this study.

Additionally our RPE data showed that the majority of our subjects identified the 45 Hz, 4 mm condition as the most intense when compared to the other experimental conditions, while performing push ups. The other combinations of frequency and amplitude were statistically equivalent to the NV condition. It is common in the exercise field and also in experimental procedures to use lower combinations of both vibration parameters to introduce individuals to a vibration stimulus. Our data suggests that the only purpose of using the lower combinations of frequency and amplitude tested in this investigation may in fact be for introduction or adaptation to the vibration stimulus, since the upper body muscles were unaffected by these combinations. Recently, Mischi and Cardinale (2009) however, found that vibration set at 28Hz was beneficial for increasing co-contraction of the TB and BB in their study on arm flexors. Their data indicates that vibration stimulation results in an increase in co-activation of agonist and antagonist muscle groups, especially when using lighter loads. Stimulus from the WBV platform in the push up position did not produce such results, but lower parameter settings may still help individuals adjust to the higher parameter settings which are necessary for

producing significant increases in EMG_{RMS} activity and potentially increasing strength and performance.

The key finding from this study is that only one vibration condition produced a significant increase in the TB which is a primary mover, but also in the BB which is not a primary muscle group for the push up and these results were due to their proximity to the WBV platform. The commonality between the TB and BB is their anatomical location; one being the agonist and the other, the antagonist mover for the elbow. Co-contraction of these two muscle groups is believed to increase joint stability at the elbow joint and ultimately increase transmissibility of vibration stimulus (Feltham et al, 2006). It can be speculated that vibration stimulus causes excitation of the muscles in which it resonates and this may be the reason for the lack of vibratory stimulation recorded in PM and LD. We hypothesize that the number of joints that the vibration was attempting to effectively pass through, and the complexity of the shoulder joint, were key factors contributing to the inactivity in the PM and LD during vibration in this investigation.

Summary

The purpose of this research project was to determine if direct contact with the vibrating stimulus in a push up position would enhance upper body EMG muscle activity and which combinations of vibration parameters would stimulate the greatest increases. The results demonstrated that the vibration stimulus from a WBV platform set to 45 Hz and 4 mm resulted in statistically significant increases in the TB and BB, however no other pairing of frequency and amplitude resulted in any significant increases in any of the PM, LD, TB, and BB. The data collected further indicates that HR may be a poor indicator of muscular fatigue during short bouts of WBV exposure and must be carefully used as a tool to assess fatigue longevity following acute exposures to vibration stimulus. RPE data was somewhat representative of changes in EMG_{RMS} but testing procedures must be controlled more thoroughly in order to understand whether or not it is an effective tool to assess WBV effects. Our EMG data suggests that direct contact is necessary to increase EMG_{RMS} activity in the TB and BB when compared to the squat position. However it may not be possible to stimulate significant increases in the distal muscles of the upper body (PM and LD) because of their anatomical distance from the vibration source, the number of joints which separate them from the platform and the complexity of the shoulder joint.

Future Directions

Results from the current experiment suggest that perceived intensity of stimulus may not be an accurate way to assess exercises performed on a WBV platform. The platform makes a distinct noise, especially when at the higher parameter settings and this could have affected the subject's ability to distinguish between intensities. It might be interesting to perform a similar experiment with the platform and controlling for the influence of platform noise, to determine if RPE is a valid measurement tool for vibration training.

It may also be beneficial to the field of research if accelerometers were placed at wrist, elbow and shoulder joints in a related study using a WBV platform and a traditional upper body exercise. The research on transmissibility through the upper body has been generated almost exclusively from biomechanics and workplace related research. The transmissibility of vibration energy through the upper body muscle and joints during dynamic exercise on a WBV platform needs to be explored.

Further research investigating the effects of increased load on the upper body is also necessary. This can be accomplished by elevating the feet to increase the gravitational load on the muscles, or simply providing a back pack with weights in it. In theory, increased load may in fact increase joint stability around the elbow joint and perhaps the shoulder which may improve transmissibility through both of those joints. Increasing load on the lower body in the squat position has been studied, and in order to fully understand the effects of vibration stimulus on upper body musculature, increasing the load supported during upper body exercise should be investigated.

A comparison study between a traditional upper body training protocol and one which includes vibration stimulus would provide a better understanding of vibration effects over time. If such a study were to be conducted using push ups on a vibrating platform, I would suggest that surface EMG electrodes be placed on other muscles in the hand arm system such as the anterior and posterior deltoids. Many of the observations that are reported following acute training studies need to be validated with longitudinal data to substantiate the theories made in reference to strength and performance gains.

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APPENDIX A



CONSENT TO PARTICIPATE IN RESEARCH

Study : **The Effect of the Whole Body Vibration Stimulus on Upper Body Muscle Activity While Performing Push Ups**

You are being asked to participate in a research study (REB # 06-035) conducted by Mr. Sadiki Robertson, Dr. J. Jakobi, and Dr. K. Kenno from the Department of Kinesiology at the University of Windsor. If you have any questions or concerns about the research, please feel free to contact Dr. Kenji Kenno at (519) 253-3000 x 2444.

PURPOSE OF THE STUDY

The purpose of this study is to determine the vibration platform frequency and amplitude to optimally stimulate upper body EMG activity during dynamic push ups. Vibration is applied through a platform that vibrates at a given frequency and displacement. The vibration sensation is similar to a high-intensity massager that is applied from a platform you are performing push ups on and has been described as comfortable and relaxing.

PROCEDURES

If you volunteer to participate in this study, we would ask that you do the following things:

1. Complete a health survey (PAR-Q) to assess your current physical capability.
2. You will be asked to report to the lab where you will receive an introduction to the whole body vibration platform. You will first be asked to stand in a squatted position on the platform to get used to its sensation and then progress to performing push ups on the platform. Push ups will also be performed on a force platform to determine the weight supported during a push up. This session will take no longer than 30 minutes.
3. Experimental Session: This session will be approximately 1 week after session 1 and the investigator will apply surface EMG electrodes (small discs) to skeletal muscles of the upper body as well as a goniometer to the elbow joint (measures joint angle). You will then perform MVE (maximal voluntary exertions) for each upper body muscle being analyzed. These are completed by contracting the selected upper body skeletal muscles as maximally as possible against resistance provided by the investigator. These MVE will provide a reference point for your maximal muscle activity.
4. You will then be asked to perform 7 push ups at a cadence of 1 second for the down phase and 1 second for the up phase in each trial while on the vibrating platform. These trials will be randomly performed with or without vibration. The randomly assigned conditions are :
 1. 7 push ups with no vibration
 2. 7 push ups at 25Hz-2mm
 3. 7 push ups at 25Hz-4mm
 4. 7 push ups at 35Hz-2mm
 5. 7 push ups at 35Hz-4mm
 6. 7 push ups at 45Hz-2mm
 7. 7 push ups at 45Hz-4mm

5 - 7 minutes of rest will be provided between each experimental condition. At the end of each experimental condition you will be asked to rate the intensity of the push ups based on what is called a Borg scale (1- 10) of exercise intensity.

All sessions will be conducted in the Exercise Physiology Lab (Rm 230) on the second floor of the Human Kinetics Building. Results from this experiment will be available by August 1st, 2008 on the University of Windsor Research Ethics Board website: www.uwindsor.ca/reb under Study Results. They will also be published in a study in a reputable academic journal.

POTENTIAL RISKS AND DISCOMFORTS

There are minimal risks associated with this study. Muscle soreness and/or fatigue is a possibility but it is not anticipated with the duration of the applied whole body vibration stimulus being short (~30 sec) and the extended rest periods provided (5 minutes) between each set of push ups.

POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The results of these studies will determine the amount of upper body muscle activity during WBV exposure while performing push ups at various frequencies and amplitudes. These results will help in the development of a dynamic whole body vibration skeletal muscle strength training protocol. Subjects will also become familiarized with a new type of resistance training.

PAYMENT FOR PARTICIPATION

You will not receive payment for participation in this study.

CONFIDENTIALITY

Any information that is obtained in connection with this study that can identify you will remain confidential and will be disclosed only with your permission.

Data will be collapsed before results are printed. All subjects will be assigned an arbitrary number to ensure anonymity. Data will be stored for one year in a password protected file and then disposed of. Raw data will not be released to any other parties.

PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you feel are inappropriate and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE SUBJECTS

Upon completion of the research project, the results will be available on the University of Windsor Research Ethics Board website: www.uwindsor.ca/reb under the section of Study Results by August 1st, 2008. I also plan to publish this study in a reputable academic journal upon the completion of the research.

SUBSEQUENT USE OF DATA

This data will be used in subsequent studies.

Do you give consent for the subsequent use of the data from this study?

☐ Yes

☐ No

RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. If you have questions regarding your rights as a research subject, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; telephone: 519-253-3000, ext. 3916; e-mail: lbunn@uwindsor.ca.

SIGNATURE OF RESEARCH SUBJECT/LEGAL REPRESENTATIVE

I understand the information provided for the study *The Effect of Whole Body Vibration on Muscle Activity* as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

Name of Subject

Signature of Subject

Date

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

Signature of Investigator

Date

APPENDIX B

PAR-Q & YOU

Physical Activity Readiness

Questionnaire - PAR-Q (revised 2002)

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES NO

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
2. Do you feel pain in your chest when you do physical activity?
3. In the past month, have you had chest pain when you were not doing physical activity?
4. Do you lose your balance because of dizziness or do you ever lose consciousness?
5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
7. Do you know of any other reason why you should not do physical activity?

YES to one or more questions

If you answered

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.



DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.

- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _____

SIGNATURE _____

DATE _____

SIGNATURE OF PARENT _____ WITNESS _____

or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

Health Canada Santé Canada

© Canadian Society for Exercise Physiology

Supported by:

APPENDIX C

Borg scale for RPE

This is a category ratio scale with values from 1 to 10

0	-	nothing at all
0.5	-	extremely weak (just noticeable)
1	-	very weak
2	-	weak (light)
3	-	moderate
4	-	somewhat strong
5	-	strong (heavy)
6	-	stronger
7	-	very strong
8	-	stronger
9	-	very very strong
10	-	extremely strong (almost maximal)

This scale also has a wider range of applications than the Borg RPE scale

Appendix D

Office of the Research Ethics Board



Today's Date: April 16, 2008
Principal Investigator: Mr. Sadiki Robertson
Department/School: Kinesiology
REB Number: 08-104
Research Project Title: The Effects of Whole Body Vibration on Upper Body Muscular Activation
Clearance Date: April 15, 2008
Project End Date: June 30, 2008

Progress Report Due:
Final Report Due: June 30, 2008

This is to inform you that the University of Windsor Research Ethics Board (REB), which is organized and operated according to the *Tri-Council Policy Statement* and the *University of Windsor Guidelines for Research Involving Human Subjects*, has granted approval to your research project on the date noted above. This approval is valid only until the Project End Date.

A Progress Report or Final Report is due by the date noted above. The REB may ask for monitoring information at some time during the project's approval period.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the REB. Minor change(s) in ongoing studies will be considered when submitted on the Request to Revise form.

Investigators must also report promptly to the REB:

- a) changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
- b) all adverse and unexpected experiences or events that are both serious and unexpected;
- c) new information that may adversely affect the safety of the subjects or the conduct of the study.

Forms for submissions, notifications, or changes are available on the REB website: www.uwindsor.ca/reb. If your data is going to be used for another project, it is necessary to submit another application to the REB.

We wish you every success in your research.

Maureen Muldoon, Ph.D.
Chair, Research Ethics Board

cc: Dr. Kenji Kenno, Kinesiology
Mark Curran, Research Ethics Coordinator

This is an official document. Please retain the original in your files.



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